Fermi National Accelerator Laboratory

**CDF Clock System
Run IIa Stability/Drift Studies**

Steven J. Chappa
(630) 840-3477

PPD/EED/Collider-Beams

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1.0   Introduction

Upon the start of colliding beams operation for Run IIa at CDF, a series of stability/drift studies were initiated. These studies were designed to determine the long-term stability of 1) the accelerator signals with respect to beam, 2) the PCC module's phase-locked loop circuit (PLL), and 3) the CDF_CLK signal with respect to beam. The purpose of this document, then, is to present the results of these studies. The period under which these studies were conducted started in December of 2001 and continued up to the present (July of 2003). For the purpose of this document, however, the period of concern is from July of 2002 to the present. The reason for confining this document to the stated period of concern is due to the fact that numerous corrections and revisions were made to the Clock System's configuration prior to this period.

2.0   Drift Studies Description

Taking time measurements between two signals under study and repeating the time measurement procedure over a period of time determines drift of the signal(s). In this case, the study period is approaching 12 months. The measurement procedure basically involved using the rack-mounted scope, being properly triggered, and then directly observing the signals under study. Using the same signal source points within the Clock's configuration and by using the same scope trigger procedure, this measurement procedure was fairly straightforward in that the time measurement data was taken directly from observing the scope. However, extreme care was taken not to disturb the Clock's operation, by inadvertently pulling or moving a critical cable, during the measurement procedure since these measurements must be made during store operation.

By definition, any drift or long-term instability measurements of the Clock system must be made with respect to a predetermined beam bunch within a single Tevatron revolution. Thus all the drift measurements were made with respect to the proton bunch designated as P1. To accomplish this, a once-a-revolution scope trigger was set up in such a way so that only the proton bunch P1 is displayed along with other Clock signals. This eliminates observing any disparities that can

occur when looking at any one of the 36 bunches in a random fashion, as would happen if the scope was triggered from the PE pickup (proton downstream) signal directly.

The signals used to determine Clock drift are 1) the PE pickup signal observing P1 (the Clock System's absolute timing reference), 2) the CDF_CLK (the 132 ns clock) signal when viewed from the output of an LVDS fanout cable, 3) the low-level Tevatron RF using the CTV's (Closed Circuit Television) RF signal, 4) the marker sync pulse generated by the CAMAC 279 module which derives this marker from the TVBS (Tevatron Beam Sync) signal, and 5) the PCC module's PCLK (primary 53 MHz clock) signal. From observing these signals, four drift measurements are taken. For all measurements, the scope's trigger remains unchanged and thus consistency is maintained from the scope's "point of view" with respect to the Clock.

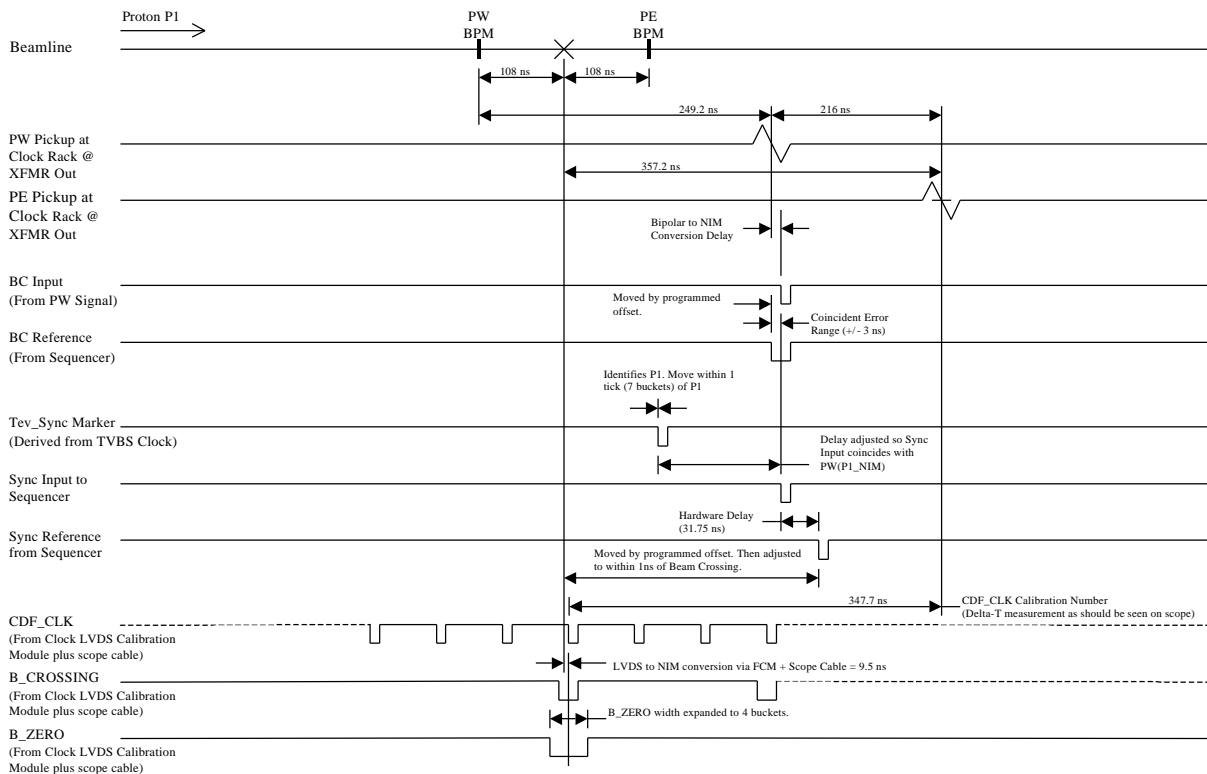10/31/2000

Clock to Beam Timing at CDF

Figure 2.0.1 -- CDF Beam Crossing to Clock System Timing Diagram

The first of these drift measurements is called the CDF_CLK Calibration Number and is the indication of overall Clock system stability. The CDF_CLK signal is the clock signal from which the detector components get their timing information with respect to beam. It is defined as the time from the CDF_CLK signal's "B_Zero edge"

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(the CDF_CLK pulse's leading edge that is coincident with the B_Zero pulse) to the zero-crossing point of the P1 proton bunch of the PE pickup signal (PE@P1). Nominally this number is 347.7 ns and its origin is illustrated in the timing diagram shown in Figure 2.0.1.

The second drift measurement is called the PE@P1 to Tev_RF Phase and is used to determine the stability of the CTV's RF signal with respect to the PE@P1 pickup signal. The measurement is defined as the time from the P1 pulse's zero-crossing point to the next leading edge (LE) of the Tev_RF pulse as displayed on the scope. Since the PCC module's PLL circuit uses the CTV's RF as its phase reference, the stability of this signal directly affects the stability of the PCC's PCLK output, thus affecting the stability of all generated Clock signals such as CDF_CLK.

The third drift measurement, called the LE TVBS to Tev_RF Phase, determines the stability of the Tevatron's once-a-revolution marker, derived from the TVBS signal. This measurement is defined as the time from the leading edge (LE) of the TVBS marker pulse to the LE of the next consecutive Tev_RF pulse as seen on the scope. The stability of this marker, with respect to the CTV's RF signal, is important since the ANDing of these two signals, as shown in Figure 5.2.1, produces the Tev_Sync signal that the PCC module uses to identify P1.

The fourth drift measurement, called the Tev_RF to PCLK Phase, determines the stability of the PCC module's PLL circuit and is done by comparing its Tev_RF input signal (from the CTV's RF) with its PCLK output signal. This measurement is defined as the time from the leading edge LE of any Tev_RF pulse to the LE of the next consecutive PCLK pulse as seen on the scope.
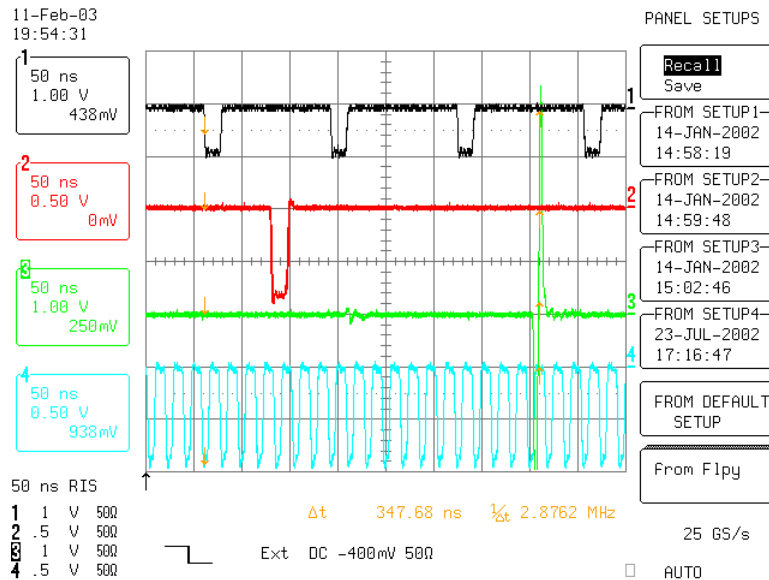
3.0   Drift Measurement Procedure

As previously stated, the measurements must be conducted during beam colliding stores. In addition and prior to taking any measurements, the Clock's operation should be checked. This is to verify that the time measurements that determine the magnitude of drift are taken under the same operating conditions for every measurement. The easiest way to verify Clock operation is to first check the PCC and Sequencer modules' operation via their front panel outputs/monitors (no red LED error lights lit while in Normal operation). Then, the timing operation is checked via the scope's standard monitoring picture. Scope Picture 3.0.1 illustrates the standard monitoring picture, called the CDF Beam to Clock System Timing picture, and is used for the operations check.

Once proper operation of the Clock is verified, the following steps are then used to perform the drift measurements:

1. **CDF Clock Calibration Number:** From the CDF Beam to Clock System Timing scope picture (recalled from Panel Setup1), the time measurement

cursors are set as shown in Scope Picture 3.0.1: the reference cursor set to the -400 mV level (NIM threshold) of the CDF_CLK pulse @ B_ZERO (displayed on CH1), the difference cursor set at the zero-crossing point of the PE@P1 signal (displayed on CH3). The corresponding Δt displayed is the calibration number to be recorded.

Scope Picture 3.0.1 -- CDF Beam to Clock System Timing
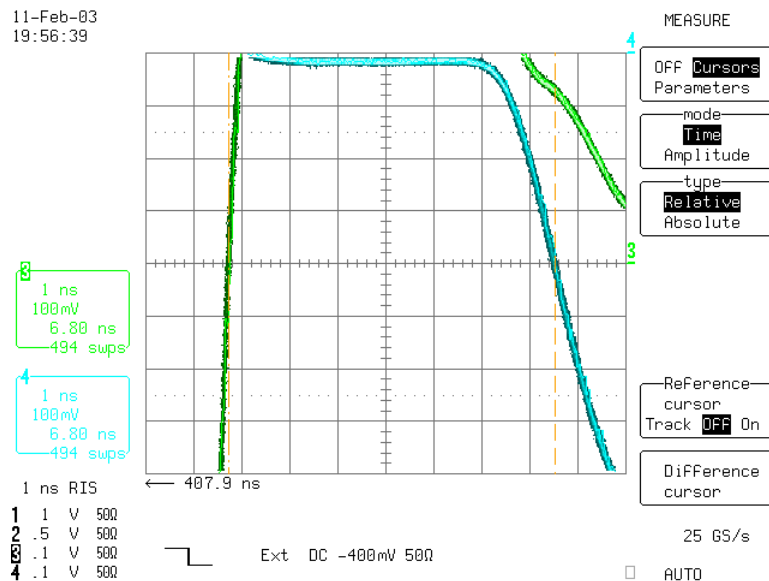
Scope Picture 3.0.2 -- PE@P1 to Tev_RF Phase

2. **PE@P1 to Tev_RF Phase:** From Scope Picture 3.0.2 (recalled from Panel Setup3), the cursors are set to indicate the time between the zero-crossing point of the displayed PE@P1 pulse and the NIM threshold of the next

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leading edge of the Tev_RF signal. The corresponding Δt displayed is the phase number to be recorded.

3. **LE TVBS to Tev_RF Phase:** From Scope Picture 3.0.3 (recalled from Panel Setup4), the cursors are set to indicate the time between the leading edge's NIM threshold (-400 mV) of the TVBS signal pulse and the NIM threshold of the next leading edge of the Tev_RF signal. The corresponding Δt displayed is the phase number to be recorded.

CH1: Not displayed
CH2: TVBS from 821's CH1 single output
CH3: PE Signal from XFMR module (not shown)
CH4: Tev_RF from 821's CH2 single output
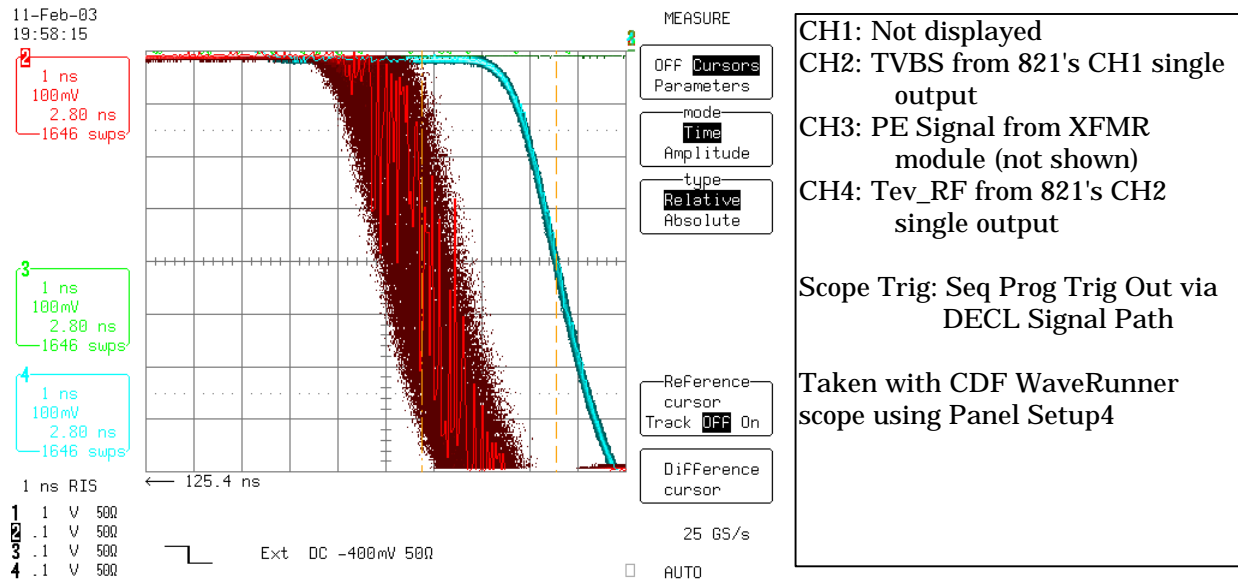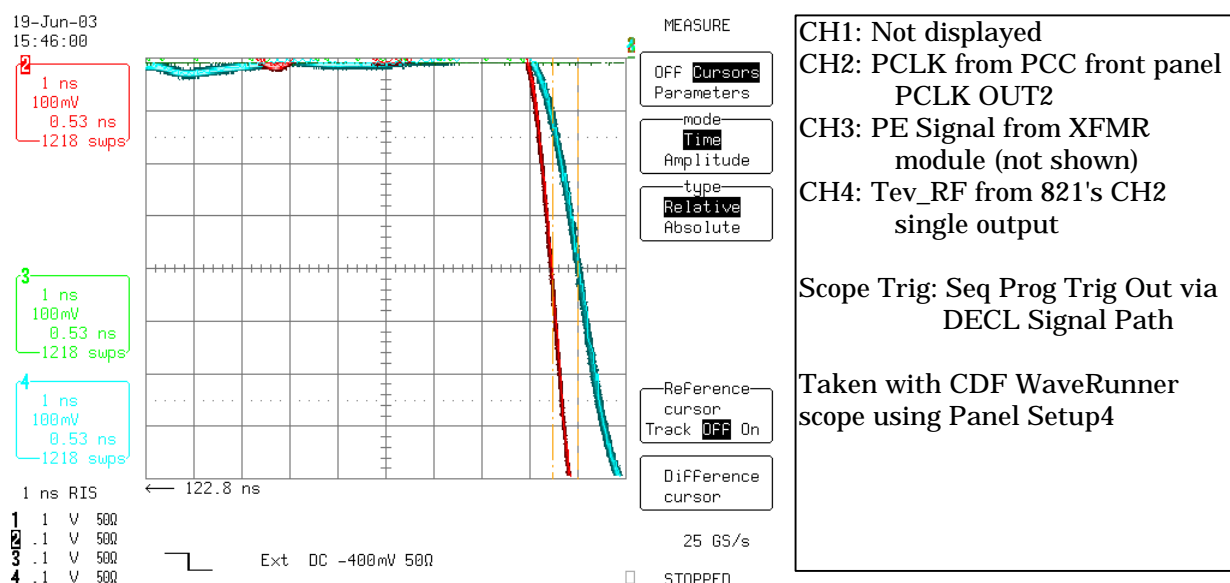
Scope Trig: Seq Prog Trig Out via DECL Signal Path

Taken with CDF WaveRunner scope using Panel Setup4

Scope Picture 3.0.3 -- TVBS to Tev_RF Phase

4. **Tev_RF to PCLK Phase:** Using the same scope setup as shown in Scope Picture 3.0.3, the scope channel's input cable's connection is moved from the 821's CH1 single output to the PCC's PCLK2 front panel output. The result is as shown in Scope Picture 3.0.4. Using this scope picture, the Tev_RF to PCLK Phase time measurement is taken using the scope's cursors. Note that the exact position of the cursor is set at the observed center of the trace (being referenced). Also, the horizontal center grid is the vertical reference point for all traces and all time measurements. In the data chart (Chart 4.0.1), a negative (-) recorded measurement value means that the PCLK edge observed occurred just prior to the Tev_RF edge observed.

In addition to the above four recorded measurements, the stability of the Clock's signal generation and fanout is checked. This is done during the first measurement using the CDF Beam to Clock System Timing picture (Scope Picture 3.0.1). The scope's timebase is set to 5 ns/div and the timebase delay knob is adjusted until the CDF_CLK's leading edge (@B_ZERO) is aligned with the center vertical gridline. The timebase delay reading should be at 37.0 ns. This has been the case for all measurements since the drift measurements were done and has not since changed.

19-Jun-03
15:46:00

1 ns
100mV
0.53 ns
1218 swps

MEASURE

OFF Cursors
Parameters

mode
Time
Amplitude

type
Relative
Absolute

3
1 ns
100mV
0.53 ns
1218 swps

4
1 ns
100mV
0.53 ns
1218 swps

Reference
cursor
Track OFF On

Difference
cursor

1 ns RIS

1 1 V 50Ω
2 .1 V 50Ω
3 .1 V 50Ω
4 .1 V 50Ω

← 122.8 ns

Ext DC -400mV 50Ω

25 GS/s

STOPPED

CH1: Not displayed
CH2: PCLK from PCC front panel
        PCLK OUT2
CH3: PE Signal from XFMR
        module (not shown)
CH4: Tev_RF from 821's CH2
        single output

Scope Trig: Seq Prog Trig Out via
        DECL Signal Path

Taken with CDF WaveRunner
scope using Panel Setup4

Scope Picture 3.0.4 -- PCLK to Tev_RF Phase

4.0   Drift Measurement Data

The data resulting from the described (in Section 3.0) four measurements, along with the beam store parameters, is arranged in the following table.

Week No.	Date	Time	Store No.	Outside Temp (Deg F)	CDF_CLK @B_Zero to PE@P1 (ns) (CDF_CLK Cal No.)	PE@P1 to Tev_RF Phase (ns)	Tev_RF to PCLK Phase (ns)	LE TVBS to Tev_RF Phase (ns)	LE TVBS to PE@P1 Δt Calc. (ns)
*1	07/01/02	16:24	1486	89.2	347.84	2.38	+1.30	7.18	4.80
2	07/08/02	13:20	1507	94.7	347.96	2.38	+1.28	7.78	5.40
3	07/15/02	18:30	1530	79.7	347.88	2.30	+1.28	7.40	5.10
*4	07/23/02	16:57	1574	71.0	348.84	4.45	-1.63	5.60	1.15
5	08/01/02	18:03	1613	86.5	348.76	4.63	-1.65	5.13	0.50
6									
7	08/12/02	08:11	1657	78.8	348.68	4.65	-1.65	5.75	1.10
8	08/19/02	11:27	1670	57.4	348.80	4.50	-1.63	4.88	0.38
9	08/26/02	10:17	1691	82.5	348.84	4.45	-1.65	4.48	0.03
10									
11	09/12/02	11:25	1748	79.6	348.88	4.42	-1.60	4.00	-0.42
12	09/16/02	17:14	1758	70.23	348.88	4.40	-1.58	3.73	-0.67
13	09/23/02	11:01	1781	66.9	348.84	4.48	-1.60	2.48	-2.00
14	10/04/02	16:30	1824	65.1	349.24	4.00	-1.63	2.20	-1.80

15	10/07/02	10:16	1830	53.4	348.76	4.48	-1.63	1.63	-2.85
16	10/14/02	13:22	1845	53.2	348.72	4.60	-1.65	0.88	-3.72
*17	10/21/02	13:05	1888	52.3	347.56	4.88	-0.55	3.77	-5.11
18	10/28/02	15:16	1918	47.5	347.28	5.13	-0.58	4.70	-4.43
19	11/04/02	14:18	1940	42.7	347.08	5.35	-0.63	4.08	-5.05
20	11/13/02	11:37	1961	57.4	346.88	5.35	-0.60	3.95	-5.40
21	11/20/02	15:13	1981	45.6	346.60	5.68	-0.63	3.30	-6.38
22									
23	12/02/02	16:50	2019	19.3	346.12	6.23	-0.65	2.55	-7.68
24	12/12/02	09:59	2070	27.3	346.08	6.30	-0.65	2.08	-8.22
25	12/16/02	17:40	2078	24.7	346.16	6.28	-0.63	2.43	-7.85
26	12/26/02	16:08	2103	20.75	345.88	6.58	-0.60	2.40	-8.18
27									
28	01/10/03	16:02	2153	15.1	345.76	6.60	-0.63	2.27	-8.33
29									
30									
31									
32									
*33	02/11/03	19:37	2208	15.6	347.68	6.80	-2.60	2.65	-10.15
34	02/21/03	13:11	2260	41.7	347.52	6.92	-2.60	2.65	-10.27
35	02/24/03	17:08	2271	9.8	347.60	6.78	-2.60	2.75	-10.30
36									
37	03/12/03	09:59	2307	45.0	347.60	6.75	-2.60	3.27	-9.48
38	03/17/03	10:25	2321	71.1	347.76	6.50	-2.60	3.65	-8.85
39	03/24/03	10:13	2343	63.9	348.32	6.00	-2.57	4.95	-7.05
40	04/02/03	14:30	2383	60.5	348.64	5.70	-2.63	5.15	-6.55
41	04/07/03	09:38	2402	27.2	348.60	5.80	-2.61	4.80	-7.00
42	04/17/03	09:58	2436	39.4	349.16	5.30	-2.63	5.65	-5.56
43	04/21/03	10:30	2445	43.9	349.00	5.48	-2.63	5.95	-5.53
44	04/28/03	09:43	2490	63.8	349.32	5.13	-2.63	6.43	-4.70
45	05/05/03	10:36	2507	63.7	349.16	5.28	-2.60	6.90	-4.38
46	05/13/03	17:25	2540	63.4	349.40	5.05	-2.63	7.25	-3.80
*47	05/19/03	10:20	2562	62.3	347.44	4.85	-0.55	4.97	-2.88
48									
49	06/02/03	15:14	2636	63.8	346.88	5.48	-0.55	5.00	-3.48
50	06/10/03	16:37	2671	74.1	346.92	5.33	-0.55	5.92	-2.41
51	06/16/03	11:57	2689	83.1	347.28	5.05	-0.55	6.23	-1.82
52	06/23/03	11:28	2715	86.1	347.52	4.85	-0.53	6.70	-1.15

Chart 4.0.1 -- Drift Measurement/Calculation Data Chart

The outside temperature is included with the chart's time measurement data in order to correlate any trends in the drift measurements with changes in outside

temperature. The measurement recorded was taken from the Accelerator's ACNET display in the CDF control room.

The last column deals with the true drift of the TVBS signal, as received at the Clock rack, in relation to the PE pickup signal. The data value shown is a calculated value and its derivation will be discussed in Section 5.2.

An (*) in front of the week number indicates that the measurement was taken just after a system configuration change. The chart below summarizes the Clock system configuration changes that were made during the studies period.

Week No. (Date)	Reason For Change	Change to Tev_RF cable to PCC	Change to TVBS cable From P.Panel	792 Switch Delay change (setting)	Other Changes
1 (7/1/02)	PCC module upgrade and system adjustments	none	(-) 4.0 ns	none (8)	PCC Module MCLK Dly $A to $B
4 (7/23/02)	CTV RF signal change Recalibrate Clock System timing	(+) 16.0 ns	(-) 13.0 ns	(+) 18.0 ns (16+8+2)	none
17 (10/21/02)	Drift recalibration	(+) 1.0 ns	(-) 4.0 ns	(+) 1.0 ns (16+8+2+1)	none
33 (2/11/03)	Timing recalibration after shutdown	(-) 2.0 ns	(-) 2.0 ns	(-) 2.0 ns (16+8+1)	CAMAC 279 reloaded dly setting
47 (5/19/03	Drift recalibration	(+) 2.0 ns	(+) 3.0 ns	(+) 2.0 ns (16+8+2+1)	none

Chart 4.0.2 -- Clock System Configuration Changes Summary

5.0 Graphical Representation of the Drift Measurements

In order to identify trends, ranges, and correlations, the drift measurement data and the TVBS calculated drift data presented above is depicted graphically on the following pages. Two of the three graphs are used to represent (in section 5.1) the actual drift of the Clock signals, as seen by the Clock and the detector components, with respect to beam. The third graph in section 5.1 represents the stability of the PCC module's PLL circuit. Section 5.2 is used to illustrate the drift of the leading edge of the Tevatron's TVBS marker signal (LE TVBS signal) and to correlate this drift with the outside temperature. Although the TVBS signal is not used directly

for Clock signal generation (as is the case with the Tev_RF signal), it is used for critical gating functions and for identification of P1.

5.1   Clock Signal Drift Measurements

The set of three graphs on the following page depicts the drift magnitude of the Clock signals with respect to beam (PE@P1 proton bunch). The top graph illustrates the drift, in addition to the timing corrections, of the Clock's CDF_CLK signal edge as identified by the B_ZERO signal. The timing relationship between this edge and PE@P1's zero-crossing point is shown previously in the Clock System's to Beam Timing diagram (Figure 2.0.1). It is referred to as the CDF _CLK Calibration Number and has a nominal value of 347.7 ns. Any deviation from this nominal value represents a timing error, as seen by the detector users, when compared to beam collisions. Note that the graph's curve is not continuous. The curve's dashed segments indicate that a configuration change occurred prior to the recorded measurement being taken. Any change in the configuration (Tev_RF cable delay) will directly affect the CDF_CLK calibration number and will be indicated in the graph.

The middle graph depicts the drift magnitude of the Tev_RF signal as seen by the Clock system. This drift is important to the Clock since any drift in this signal with respect to beam will be directly transferred to the Clock's primary clock signal (PCLK). It is from this primary clock signal that all generated Clock signals are derived. Unlike the top graph of the CDF_CLK calibration number, the Tev_RF drift is continuous. Configuration changes (Tev_RF cable delay) do not affect the Tev_RF drift measurement since the scope's Tev_RF monitoring source is before, within the Tev_RF's signal path, the Tev_RF signal cable being adjusted. The only exception happened after week number 4. Here, a configuration change/correction was implemented after the Tev_RF and the TVBS signal experienced a significant and abrupt change that occurred "upstream" from CDF.

The third graph depicts any drift change of the PCC module's PLL circuit by comparing the PLL's input (Tev_RF) with the PLL's output (PCLK). Again, the dashed curve segments indicates a configuration change (Tev_RF cable delay). The Tev_RF source for this measurement is the same as that for the Tev_RF drift measurement (described above). Therefore, configuration changes to the PCC's Tev_RF input cable is reflected in the PCC's PLL circuit drift measurement.
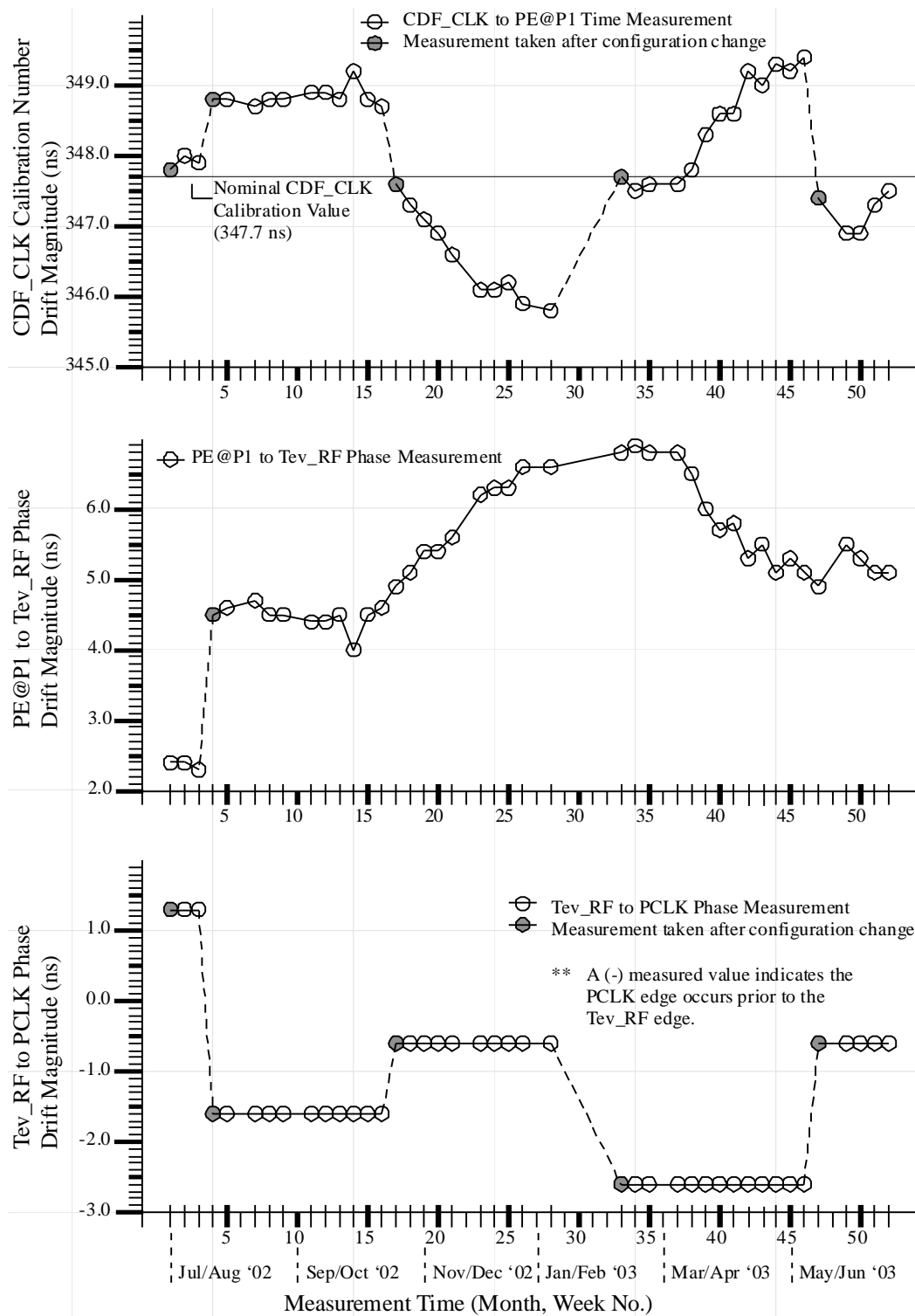
Figure 5.1.1 -- **Graphical Representation of the CDF Clock Signal Drift Measurements**

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5.2   CDF TVBS Signal Drift

As previously stated, the TVBS marker signal is used by the Clock to identify a particular proton bunch (P1) within a Tevatron revolution. The Clock requires a marker signal that remains in a specific location. Due to the large amount of drift (studies during Run IA and IB indicated a drift range larger than one bucket or 18.8 ns) and the high level of jitter (in excess of 2.0 ns) previously observed on the TVBS signal's leading edge, the TVBS marker pulse cannot be used directly by the Clock's PCC module. Thus, this marker signal, with a set pulse width, is gated with the Tev_RF signal to produce a Tev_Sync pulse that is relatively "clean". However, the TVBS marker signal, as received at the Clock rack will occasionally drift outside its assigned Tev_RF pulse range. Therefore, the drift of the leading edge (LE) of the TVBS marker pulse needs to be monitored and, if necessary, be corrected for with respect to the "assigned" Tev_RF pulse.
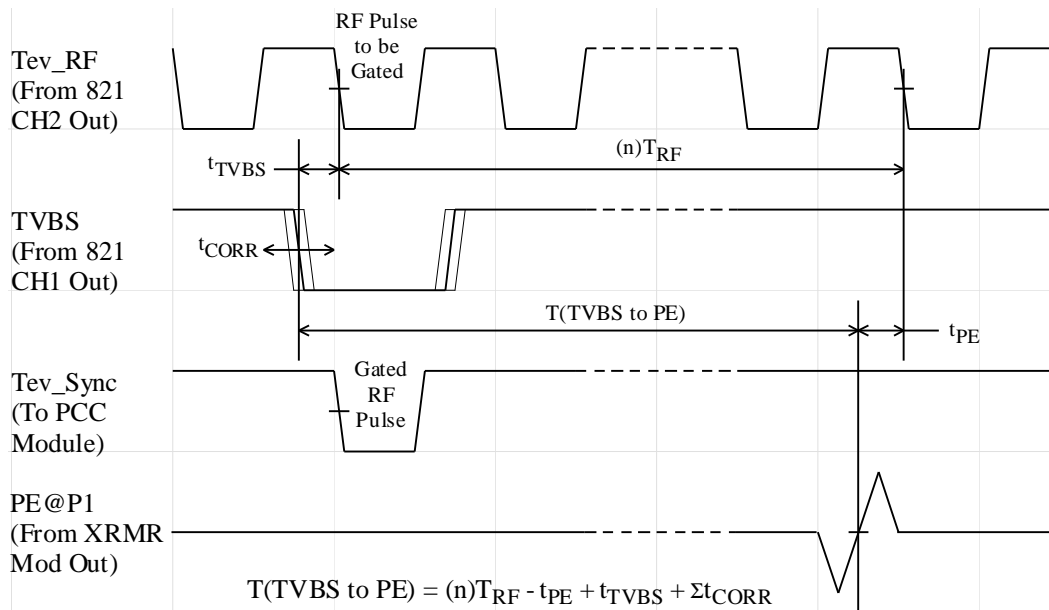

$$T(TVBS \text{ to } PE) = (n)T_{RF} - t_{PE} + t_{TVBS} + \Sigma t_{CORR}$$

Figure 5.2.1 – TVBS to Beam Timing Relationship

To determine the drift of the TVBS pulse with respect to beam, a method must first be used to determine a measured time value that directly correlates with the magnitude of the time between the TVBS signal and the beam (PE@P1). As shown in the timing diagram (Figure 5.2.1), four terms are used to determine the actual magnitude of this time delay of the LE TVBS pulse with respect to beam (the absolute timing reference). Two of the four terms, t_{TVBS} and t_{PE}, are measured values and are shown in the data chart under the columns titled "LE TVBS to Tev_RF Phase" and "PE@P1 to Tev_RF Phase", respectively. The value of these two terms changes from store to store and thus is used to determine the change in time delay, or drift, between the LE of TVBS marker and PE@P1.
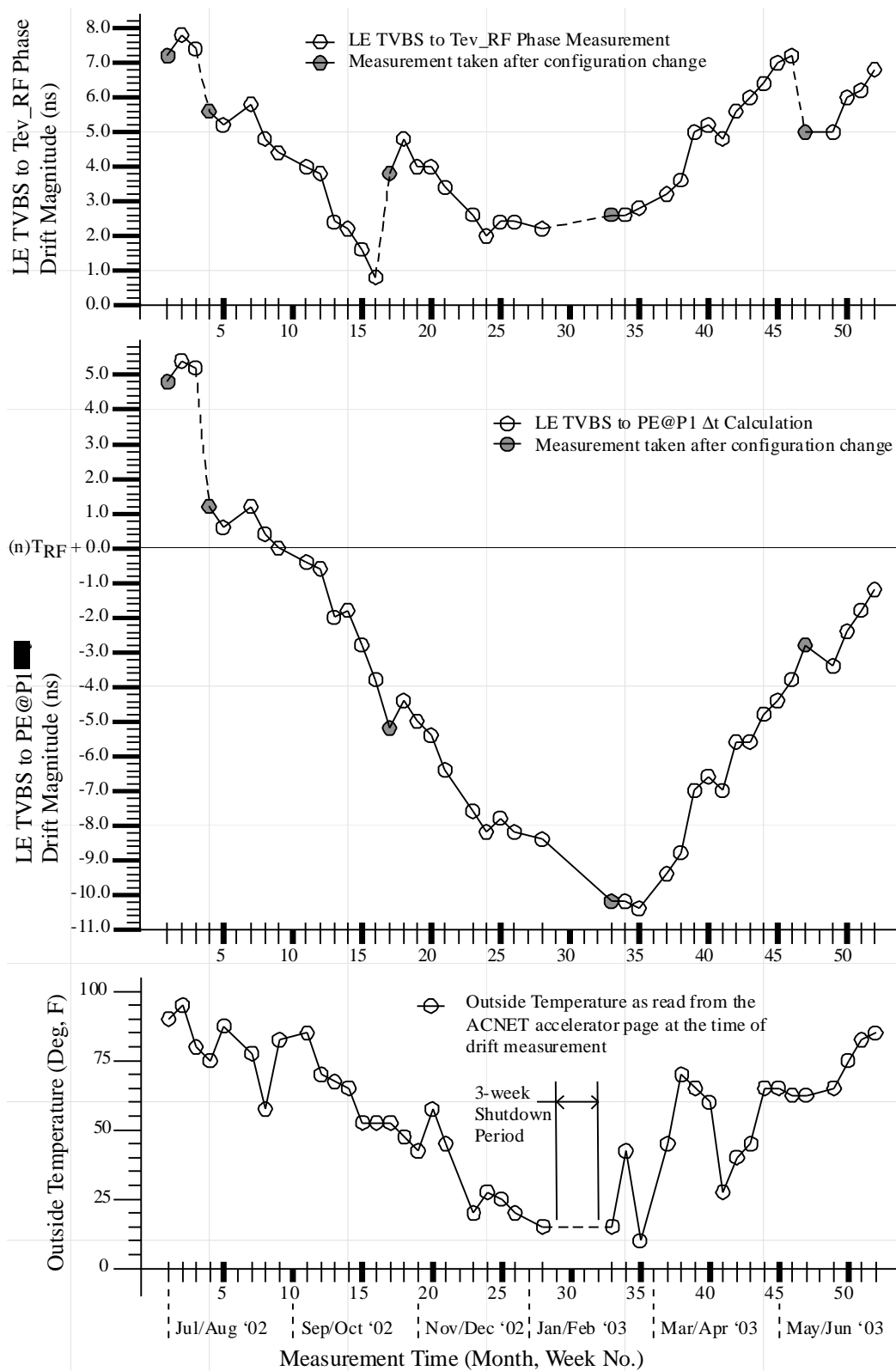
Figure 5.2.2 -- **Graphical Representation of the CDF TVBS Signal Drift Measurements**

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The remaining two terms, Σt_{CORR} and $(n)T_{RF}$, are "static" components and do not change from store to store. The term Σt_{CORR}, is the summation of the cable delay correction that was inserted (a positive value) or extracted (a negative value) from the TVBS signal cable. The summation started with week #17 since the TVBS cable correction used after week #4 was due to the abrupt and irregular CTV's RF phase change. Therefore, the sum prior to week #17 is assigned as zero. The final term, $(n)T_{RF}$, represents the integer number of Tev_RF periods between the LE of TVBS and PE@P1. During any given store (at 980 Gev) and from store to store, the Tev_RF's frequency is exceptionally stable. Counter readings at CDF put the frequency at 53.104711 MHz with a variation of 0.1 to 0.2 Hz. Therefore, the total time of any number (n) of periods of the Tev_RF signal will also be extremely constant. The data value shown in the data chart, as well as the data points on the curve, is the TVBS delay value minus the $(n)T_{RF}$ term. Since illustrating the drift magnitude does not depend on the absolute delay time but on the changes in this delay, the $(n)T_{RF}$ term is not necessary. Also, any independent movement of Tev_RF will be canceled out and will not affect the true time measurement of the TVBS marker signal with respect to beam.

The top graph of Figure 5.2.2 is an attempt to show the drift of the LE of the TVBS marker signal with respect to the LE of the next consecutive Tev_RF pulse (LE TVBS to Tev_RF Phase) only. Since the gating function previously described requires a consistent TVBS marker to Tev_RF timing, any movement of the TVBS marker signal needs to be noted and if necessary, corrected for, thus the reason for the dashed curve segments.

The middle graph of Figure 5.2.2 shows the accumulative drift of the TVBS marker signal with respect to beam (PE@P1). Now, the term Σt_{CORR} is added to the terms t_{TVBS} and t_{PE} to get the accumulation of drift up to the time of measurement. Notice that the graph is normalized using the $(n)T_{RF}$ term. Meaning, the graph is showing changes of delay around $(n)T_{RF}$. Since this graph depicts accumulated drift, no dashed curve segments are used (with the exception of week #4).

The bottom graph is used to display the outside temperatures. Notice the horizontal grid is the same for all graphs in Figure 5.1.1 and Figure 5.2.2. This is so any changes in seasonal temperatures can be correlated with changes in the drift measurements.

6.0   Conclusions

The set of graphs in Figure 5.1.1 clearly indicate that the source of drift of the Clock signals with respect to beam is the drift of the CTV Tev_RF signal. The Tev_RF to PCLK Phase graph shows almost zero change (with the exception of the configuration changes). Plus, the Clock signal fanout path drift measurement remains unchanged (at 37.0 ns) as previously stated. This would seem to indicate

that the Clock System's modules contribute little, if any, component to the drift observed. The drift's range of the Tev_RF is 2.92 ns and this range and movement of the Tev_RF signal directly correlates to the range and movement of the Clock's output signal (after allowing for configuration changes). Since the drift's range exceeds the Clock's stated signal placement specification (short-term stability) of +/- 1.0 ns, this drift needs to be periodically compensated for.

The CTV's Tev_RF signal comes from the CTV (Closed Circuit Television) system and thus is not dedicated to the CDF Clock System. Therefore, the source of the CTV's RF drift is difficult to determine. The middle graph's curve in Figure 5.1.1, when compared to the outside temperature readings, would seem to indicate that the changes are seasonal. The exception to this explanation would be the abrupt change in the PE@P1 to Tev_RF phase that was observed prior to week #4's drift measurement. Here, a change in the CTV equipment or cable somewhere "upstream" from CDF probably caused this particular change in the RF signal.

The drift range of the TVBS signal, 11.45 ns, is significantly larger than that of the CTV Tev_RF and also seems to be seasonal in nature. For reasons described in Section 5.2, this drift does not directly affect the drift of the Clock's output signals (CDF_CLK). If the drift of the TVBS pulse is greater than about +/- 5 ns, the AND function will start to include parts of adjacent RF pulses and thus the Tev_Sync will start to identify the wrong RF bucket. The result of all this is that the PCC and Sequencer modules will generate Sync_Timing and Seq_Hold errors, respectively. These are fatal Clock errors and will affect Clock signal generation. The top and middle graphs in Figure 5.2.2 show that the TVBS marker signal, without correction, will exceed this limit. The results would be similar even if the TBVS marker signal were used directly (without gating it with Tev_RF) by the PCC. Either way, the drift of the TVBS marker signal periodically needs to be corrected for.

To date, the only recourse for compensating for the drifting of the Tevatron's TVBS and Tev_RF signals is the manual correction via signal cable delays. Thus, ongoing monitoring of the Tevatron's and Clock Signals will continue and the periodic adjustments made as the need arises. Current work with the PCC II module upgrade will attempt to implement a circuit that automatically corrects for the drift of the Tev_RF signal. In this attempt, the PE pickup signal will most likely be used to set up a time reference for this correction. In addition, using the fiber-optic linked TVBS marker and Tev_RF signals will reduce the magnitude of drift, especially when compared to that of the currently used copper-cable linked TVBS signal. However, even with fiber-optic linked Tevatron signals, current studies underway at Dzero reveal that drift will still be present and will have a range of 2 to 3 ns.